## RESEARCH REPORT
(for RTOPs and Grants)

1. Title Multi-modal Image Registration and Mapping for Titan Aerobots		2. Date Prepared 01 20 2009
3. Performing Organization: Jet Propulsion Laboratory		**4. RTOP/Grant No.**

4.A. JPL Project Number: **102294-982745.03.12**	(Per GSK Policy, this serves as the **Work Authorization Document**)	4.C. NASA WBS NUMBER **982745.02.02.03.12**

5. Investigator	Telephone	6. NASA Program Manager	7. NASA Division
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8. Reference
NRA Number: NNH07ZDA001N-AISR   Other:

9. Funding Profile:	FY'08 Prior Approvals	FY'09 Current Guideline	FY'09 Current Request	FY'09 Current Overguide	FY'10 Next Request
	$ 125 K	$ 0 K	$ 0 K	$ 0 K	$ 0 K

10. Description

We were given $125 K of seed funding for one year based on the original three year proposal submitted to the AISR program. The task was originally scheduled to conclude at the end of FY'08. Due to staffing issues, we requested an extension into the first quarter of FY'09 and were granted this by the PM. At the conclusion of the task, we had expended $122,001.40.

Technical Accomplishments:
FY'08:
1. Developed prototype multi-modal image registration algorithms derived from techniques in medical imaging community for automatic registration of imagery across sensing modalities including visible, thermal and RADAR.
2. Demonstrated match capability using Cassini-Huygens data: specifically showing match between Cassini SAR and Huygens DISR mosaic with accuracy equivalent to hand registration.
3. Demonstrated match capability between Cassini SAR and VIMS instruments with match accuracy equivalent to hand registration.
4. Obtained terrestrial datasets spanning multiple spectra from two sites (Rancho Cima and Death Valley). Modes included visible, thermal IR and C- and L-band SAR.
5. Demonstrated match capability on terrestrial datasets in item 4 across wide collection of varying spectra and relative image contrast conditions.
6. Obtained datasets of Mars from Phoenix descent site.
7. Demonstrated match accuracy for data in item 6 with results identical to hand registered ground truth.
8. Developed preliminary image warping technique to achieve exact, pixel-to-pixel registration between sensor data with different image formation geometries.
9. Performed preliminary experiments on match accuracy vs. image template size, including initial timing and computational complexity experiments.

FY'09:

1. Studied inherent orientation and scale insensitivity of match algorithm and derived preliminary requirements.
2. Performed preliminary exploration of parameter space for match algorithm to determine optimal criteria for matching in widest set of cases.

Additional details are available in the attached technical report.
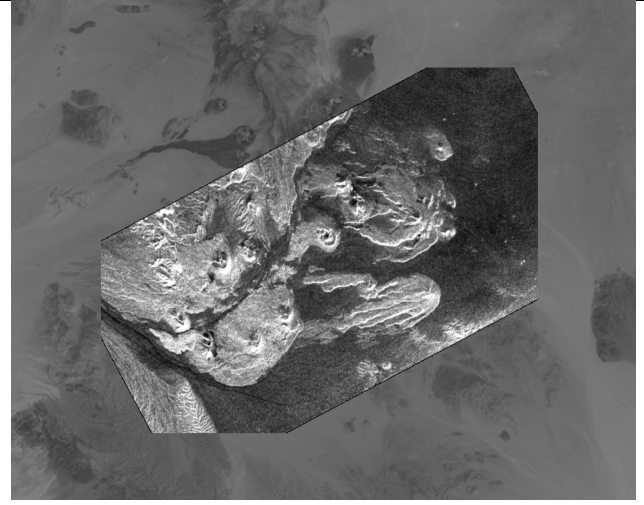
Automatic match showing overlay of C-band SAR (right inset) onto SWIR image (left). SAR data is from AirSAR (5.8 cm, TP polarization state) and SWIR data is from ASTER (1600-1700 nm band). While match is correct in a global sense, there are local misregistrations due to differences in viewpoint and fundamental imaging geometries.
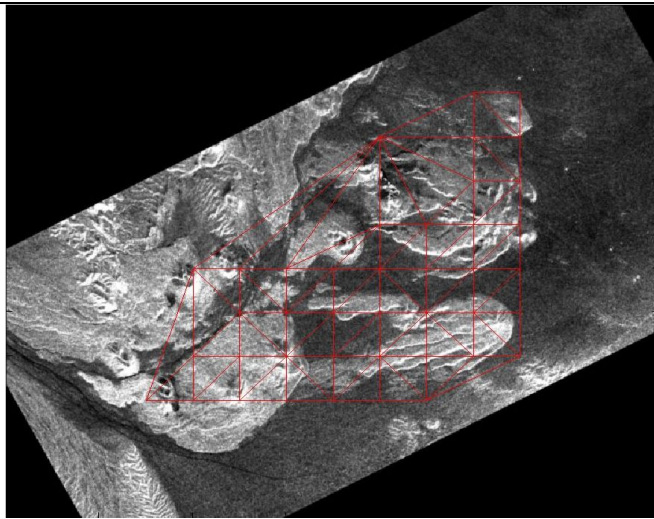
Prototype registration refinement: Triangulation of salient feature network (left) for local, nonlinear image warping resulting in better local registration (right). Image landmarks now match in spite of fundamental differences in SAR and SWIR imagery.

Milestones:

Note: Milestones were revised from the original three year proposal to accommodate reduced funding level and task duration. Milestones for descoped the effort are shown below:

FY'08:
1. Proof of concept multi-modal image registration of large regions: **Accomplished**
2. Proof of concept pixel-level registration refinement: **Accomplished**

FY'09:
1. Preliminary characterization of algorithm sensitivity and optimal parameter selection: **Accomplished**

FY'08 Travel and Presentations:
1. Presented project status and accomplishments at AISR PI meeting (May, 2008).
2. Submitted paper to IEEE Conference on Computer Vision and Pattern Recognition 2009. (Attached to this document as a JPL technical report.)

FY'09 Plans:
1. Based on results to date, a new proposal was submitted to AISR to extend this work while simultaneously broadening its scope to encompass science relevant applications more directly.

Approval:	**Date:**	**Concurrence:**	**Date:**